What is Claimed:

1   1.   A method of automatically tracing a line-structure
2   comprising an end in an image, the method comprising the steps of:

3   a.   locating a seed point;

4   b.   defining a position and a direction for the seed point;

5   c.   tracing a centerline of the line-structure from the seed
6   point; and

7   d.   stopping the centerline trace at the line-structure end.

1   2.   The method of claim 1 wherein the step of locating a
2   seed point comprises identifying a plurality of candidate seed points and
3   selecting a seed point from the plurality of candidate seed points.

1   3.   The method of claim 2 wherein the step of identifying the
2   plurality of candidate seed points comprises identifying image data points that
3   (1) are a local intensity maximum, and (2) have an intensity of at least a sum
4   of a median intensity value and an intensity standard deviation over the
5   intensity variation of the image.

1   4.   The method of claim 2 wherein the step of selecting the
2   seed point comprises calculating a position intensity and a boundary direction
3   at a plurality of boundary points surrounding the plurality of candidate seed
4   points.

1   5.   The method of claim 4 wherein the step of selecting the
2   seed point comprises evaluating the boundary directions at the plurality of
3   boundary points.

1   6.   The method of claim 4 wherein the step of selecting the
2   seed point comprises evaluating a boundary edge at the plurality of boundary
3   points.

1   7.   The method of claim 2 wherein the step of selecting the
2   seed point comprises calculating an intensity of the image surrounding the
3   candidate seed point.

1   8.   The method of claim 7 wherein the step of selecting the
2   seed point comprises evaluating the intensity homogeneity surrounding the
3   candidate seed point.

1   9.   The method of claim 1 further comprising refining the
2   seed point position by extrapolating toward the centerline from a plurality of
3   boundary points, the boundary points representing positions on a surface of a
4   generalized cylinder, and the seed point representing a position on a center
5   axis of the generalized cylinder.

1   10.   The method of claim 1 wherein the step of tracing the
2   centerline of the line structure comprises translating from the seed point to a
3   trace point.

1   11.   The method of claim 10 wherein the step of tracing the
2   centerline proceeds in a trace direction, the trace direction being the weighted
3   average of a trace direction at a plurality of boundary points.

1   12.   The method of claim 10 wherein the step of tracing the
2   centerline comprises refining a position of the trace point.

1   13.   The method of claim 1 wherein the step of stopping the
2   centerline trace comprises comparing an edge intensity of the line structure at
3   a boundary point surrounding a trace point to a threshold intensity value.

1   14.   The method of claim 13 wherein the step of stopping the
2   centerline trace comprises comparing the edge intensity of the line-structure
3   at a plurality of boundary points surrounding a trace point to a threshold
4   intensity value.

1   15.   The method of claim 13 wherein the step of stopping the
2   centerline trace comprises comparing uniformity of an interior region of the

3   line-structure with uniformity of a boundary of the line-structure in the
4   image.

1   16.   The method of claim 1 further comprising creating an
2   image analysis output, the image analysis output selected from one of a
3   graph-theoretic or a tabular representation.

1   17.   A method of automatically tracing a line-structure
2   comprising an end in an image, the method comprising the steps of:

3   a.   identifying a plurality of candidate seed points in the
4   image;

5   b.   selecting a seed point from the plurality of candidate seed
6   points, wherein the seed point represents a point on a center axis of a
7   generalized cylinder, the generalized cylinder having a cylindrical surface
8   encompassing the center axis;

9   c.   determining a plurality of boundary points corresponding
10   to the seed point, the boundary points correlating to a plurality of points on
11   the surface of the generalized cylinder;

12   d.   determining a boundary point trace direction at each
13   boundary point and determining a direction perpendicular to the boundary
14   point trace direction at each boundary point;

15   e.   positioning the seed point at an intersection of lines
16   extending from the plurality of boundary points in the direction perpendicular
17   to the boundary point trace direction; and

18   f.   tracing the line-structure to a first trace point on the
19   center axis of the generalized cylinder, the first trace point being a discrete
20   step in the trace direction from the seed point.

1   18.   The method of claim 17 further comprising:

2   g.   determining a second plurality of boundary points
3   corresponding to the first trace point;

4   h.   determining a second boundary point trace direction at
5   each boundary point corresponding to the first trace point and determining a
6   direction perpendicular to the first trace point boundary point trace direction;

7   i.   positioning the first point at an intersection of lines
8   extending from the plurality of first trace point boundary points in the
9   direction perpendicular to the first trace point boundary point trace direction;
10   and

11   j.   tracing the line-structure to a second trace point on the
12   center axis of the generalized cylinder, the second trace point being a discrete
13   step in the trace direction from the first trace point.

1   19.   The method of claim 18 further comprising determining a
2   successive trace point on the center axis of the generalized cylinder, the
3   successive trace point being a discrete step from a previous seed point.

1   20.   The method of claim 17 wherein the step of tracing the
2   line-structure comprises determining the trace direction by calculating a
3   weighted average of the boundary point trace directions.

1   21.   The method of claim 17 wherein the step of identifying
2   the plurality of candidate seed points comprises identifying image data points
3   that (1) are a local intensity maximum, and (2) have an intensity of at least a
4   sum of a median intensity value and an intensity standard deviation over the
5   intensity variation of the image.

1   22.   The method of claim 17 further comprising determining
2   an end of the line-structure.

1   23.   An image analyzing system to automatically trace a line-
2   structure comprising an end, the system comprising;

3   a. means for locating a seed point on the line-structure in an

4 image;

5   b. means for defining a position and direction for the seed

6 point;

7   c. means for tracing a centerline of the line-structure from

8 the seed point; and

9   d. means for stopping the centerline trace at the line-

10 structure end.

1   24. A program storage device readable by a machine,

2 tangibly embodying a program of instructions executable by the machine to

3 perform the method steps for automatically tracing a line-structure comprising

4 an end in an image, the method steps comprising:

5   a. locating a seed point on the line-structure in an image;

6   b. defining a position and direction for the seed point;

7   c. tracing a centerline of the line-structure from the seed

8 point; and

9   d. stopping the centerline trace at the line-structure end.

1   25. A program storage device readable by a machine,

2 tangibly embodying a program of instructions executable by the machine to

3 perform the method steps for automatically tracing a line-structure comprising

4 an end in an image, the method steps comprising;

5   a. identifying a plurality of candidate seed points in the

6 image;

7   b. selecting a seed point from the plurality of candidate seed

8 points, wherein the selected seed point represents a point on a center axis of a

9   generalized cylinder, the generalized cylinder having a cylindrical surface
10   encompassing the center axis;

11   c.   determining a plurality of boundary points corresponding
12   to the selected seed point, the boundary points correlating to a plurality of
13   points on the surface of the generalized cylinder;

14   d.   determining a boundary point trace direction at each
15   boundary point and determining a direction perpendicular to the boundary
16   point trace direction at each boundary point;

17   e.   positioning the selected seed point at an intersection of
18   lines extending from the plurality of boundary points in the direction
19   perpendicular to the boundary point trace direction; and

20   f.   tracing the line-structure to a first trace point on the
21   center axis of the generalized cylinder, the first trace point being a discrete
22   step in the trace direction from the selected seed point.